EVI-Equity

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National Renewable Energy Laboratory

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Project ID: VAN046
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Overview

Timeline

- Start: June 2021
- End: June 2022
- 80% complete (as of April 2022)

Budget

- Total project funding: $200k

Partners/Collaborators

- Georgia Institute of Technology
- Boston University
- University of Sussex
- Rutgers University
- UCLA Luskin Center
- Dartmouth College
- University of California at Davis

Barriers Addressed

- Traditional plug-in electric vehicle (PEV) charging infrastructure analysis: Primarily focused on mainstream demand.
- Little attention has been paid to disadvantaged, underrepresented, or underserved communities.
- Lack of comprehensive, yet detailed, model/tool to evaluate equitable PEV adoption and corresponding electric vehicle supply equipment (EVSE) infrastructure.

Relevance & Objective

- Support VTO Analysis program with both detailed and high-level information as to the inequity (if any) of the current and future deployment of electric vehicles and charging infrastructure.
- Develop a sophisticated analysis tool that has sufficiently high spatial resolution, while being scalable from neighborhoods (e.g., census block groups) to cities, states, and the nation.
- Quantify and investigate equitable access to and distribution of existing and future deployment of PEVs and EVSEs in neighborhoods, cities, states, and the nation.
- Consider electric vehicle adoption and charging infrastructure simultaneously in an integrated manner for more accurate assessment of the dynamic between the two.
- Incorporate broader environmental justice, energy justice, and energy equity principles, frameworks, methods, and data.
- Provide critical information for the transition towards more just and equitable vehicle electrification.

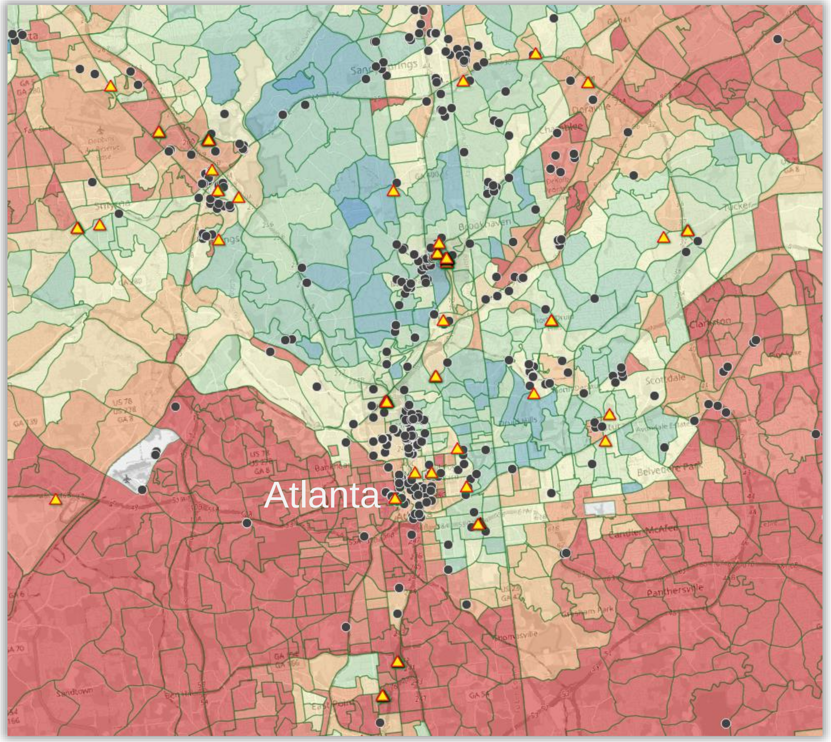
Approach: EVI-Equity (1)

- Created EVI-Equity™ (Electric Vehicle Infrastructure for Equity) model
- Scope: Entire U.S. (from 2015 to 2040)
- Spatial resolution: Census block group (CBG)
- Basic building block: Individual households in each CBG

EVI-Equity

https://www.nrel.gov/transportation/evi-equity.html

CBG-by-CBG Percentage of "People-of-Color" and Distribution of Existing Public Chargers



Percentage of "People-of-Color"

Low High

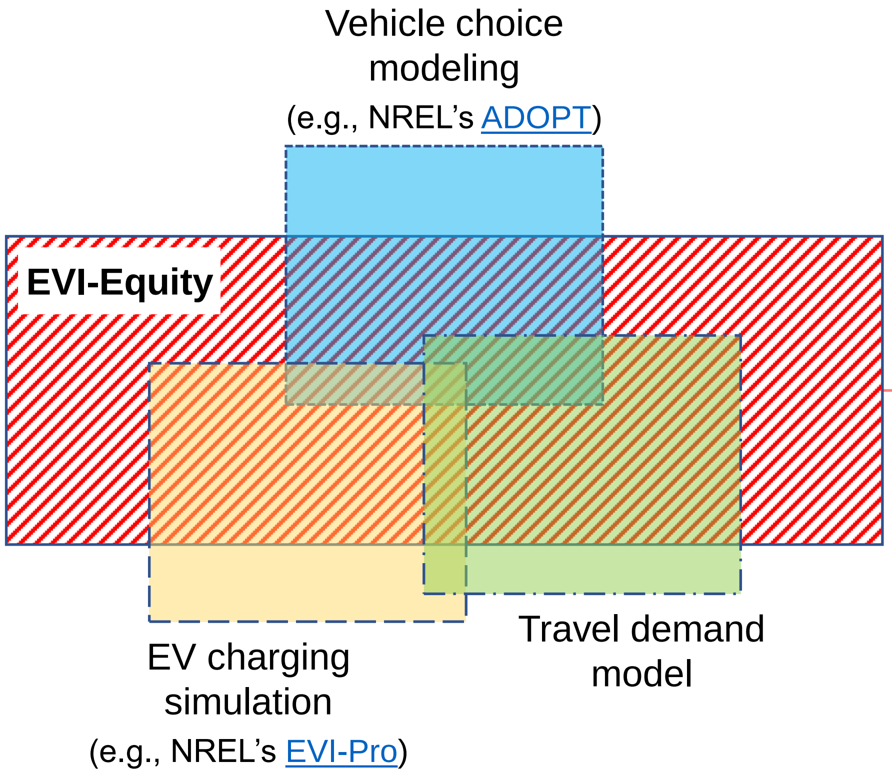
● Level 1 and Level 2 EVSE

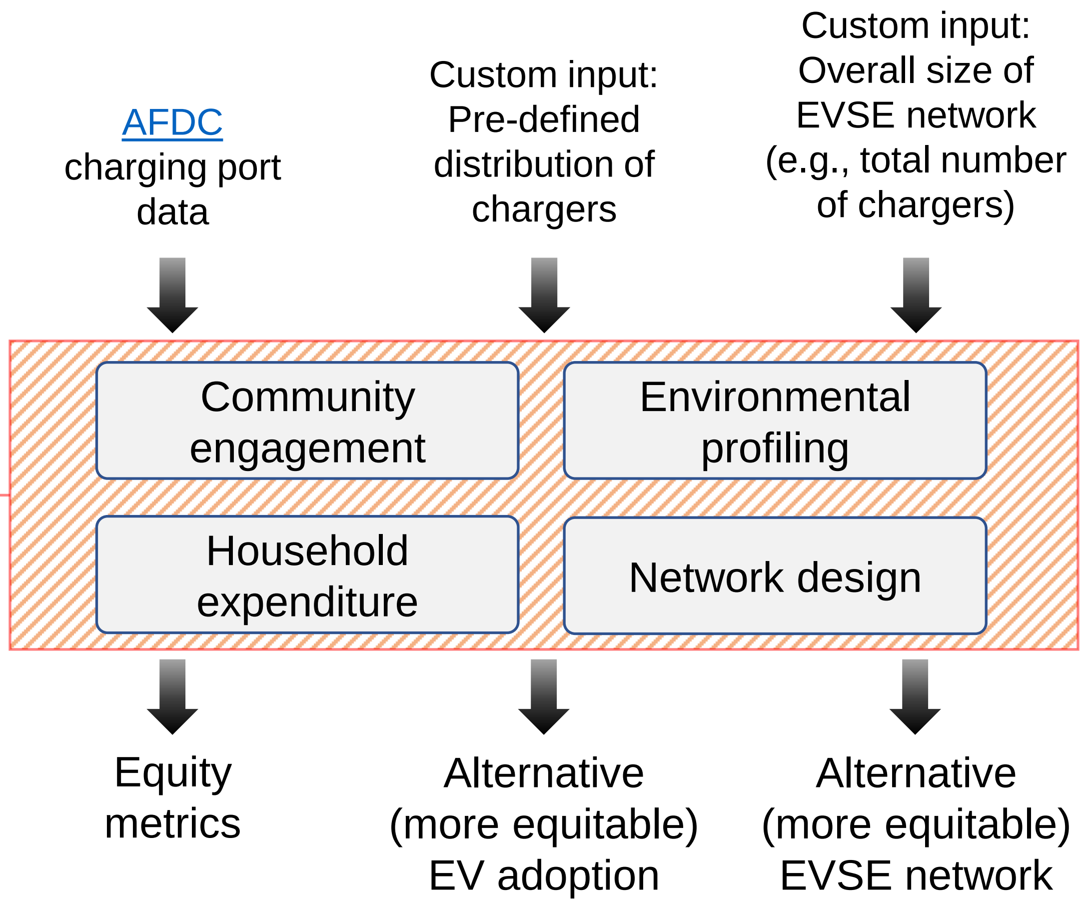
△ DC Fast Charging EVSE

The Basic Building Block of EVI-Equity: Synthetic Households

Socio-demographics and economics	Household income, expenditures, race, ethnicity, household size, occupation, education, age, etc.
Transportation	Vehicle ownership, refueling behavior, travel distance, destination type, etc.
Building	Housing type (e.g., single family detached, apartments), parking options (e.g., personal garage, on-street), utilities (e.g., electricity, natural gas), etc.
Environmental	Air quality, proximity to hazardous facilities/sites, crime rate, etc.

Approach: EVI-Equity (2)





Despite some overlap, EVI-Equity is not a vehicle choice model, EV charging simulation tool, or travel demand model.

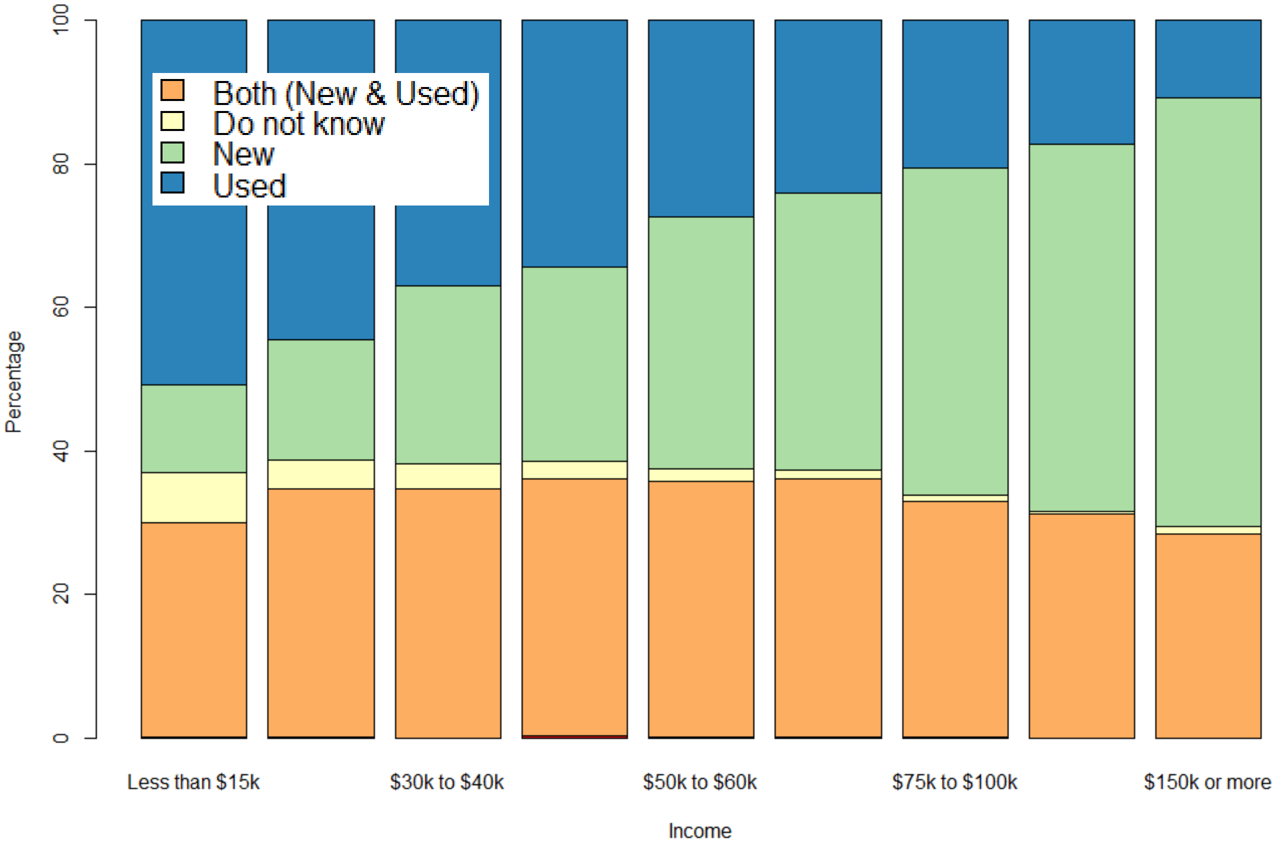
It is a cross-cutting and multi-disciplinary analysis tool, dedicated for evaluating equitable EV adoption and EVSE deployment, encompassing and bridging a wide variety of related tools, models, and frameworks.

Spatial resolution: Individual households (HHs), aggregated by census block groups (CBGs)

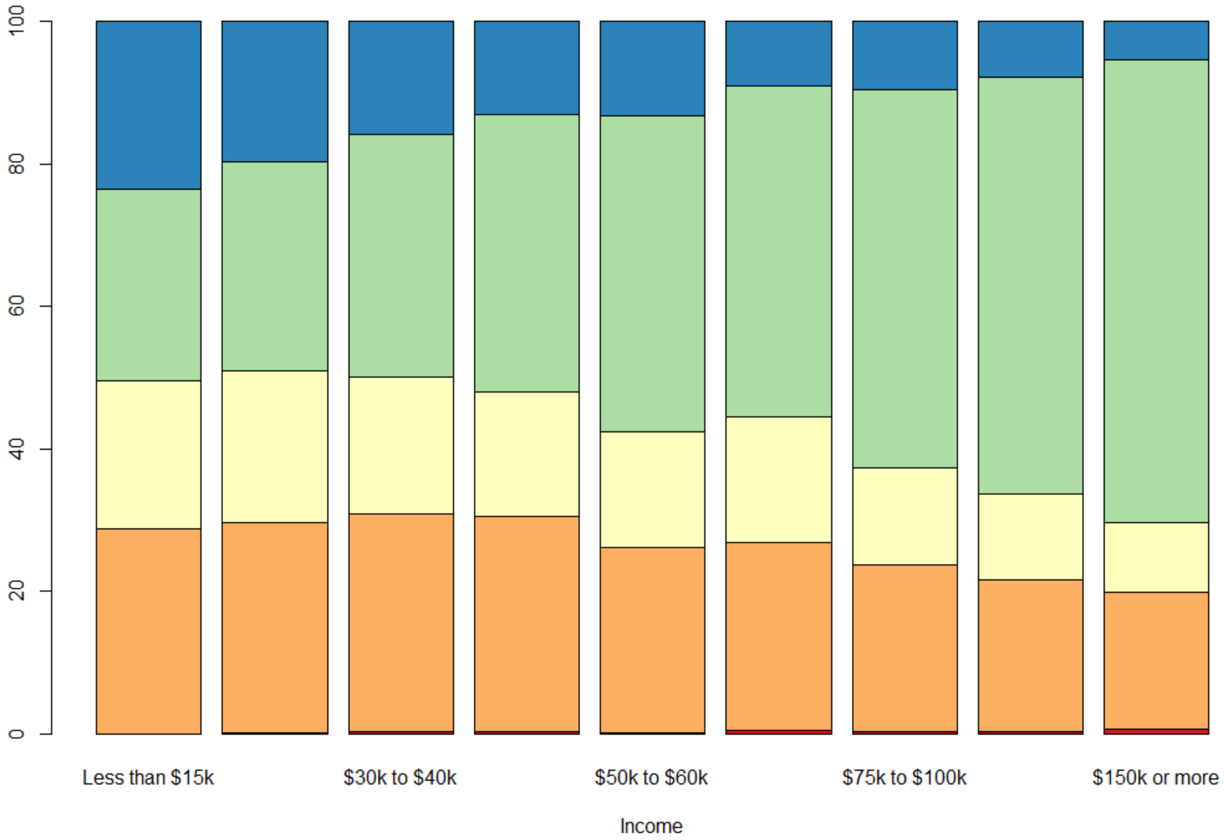
Accomplishment: Community Engagement – Public Survey

- The lower the income, the more likely respondent is to rely on the used vehicle market.
- The relative reliance on the new vs. used vehicle market may vary with technology.
- Possible contributing factors: Concerns regarding the reliability of, or lack of understanding of/familiarity with technology.

When you buy **a car**, in which market do you usually look for a vehicle?

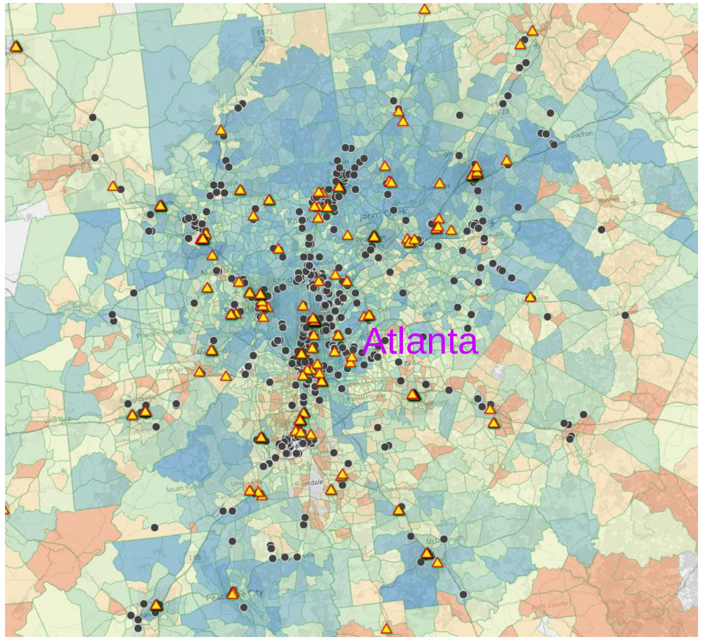


If you were ever in the market for **a plug-in electric vehicle**, which vehicle market (new and/or used) would you consider?



NOTE: More than 30 questions were asked about electric vehicles, refueling behavior and preferences, and charging infrastructure.

Accomplishment: Environmental Profiling of PEV Ownership



PEV Population by CBG

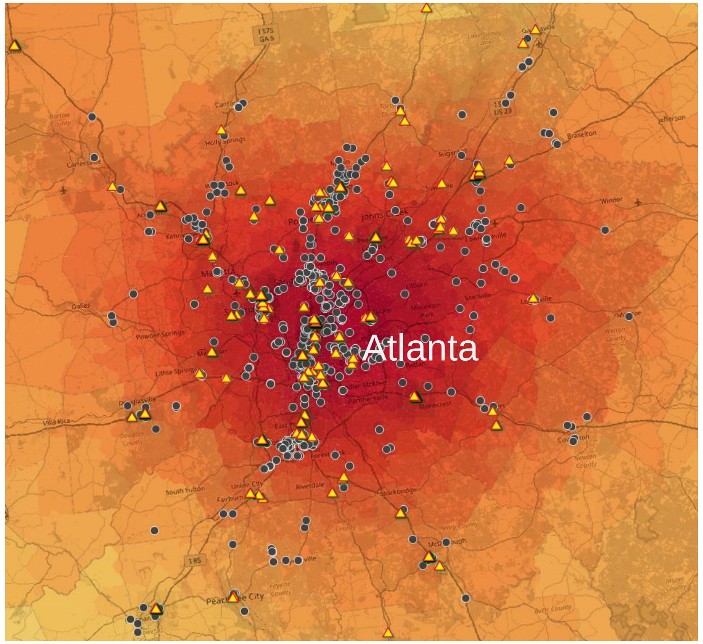
Low High

● Level 1 and Level 2 EVSE

△ DC Fast Charging EVSE

20% of PEV owners in **Georgia** live in a relatively better air quality area.

In comparison,
65% of PEV owners in **California** live in a relatively better air quality area.



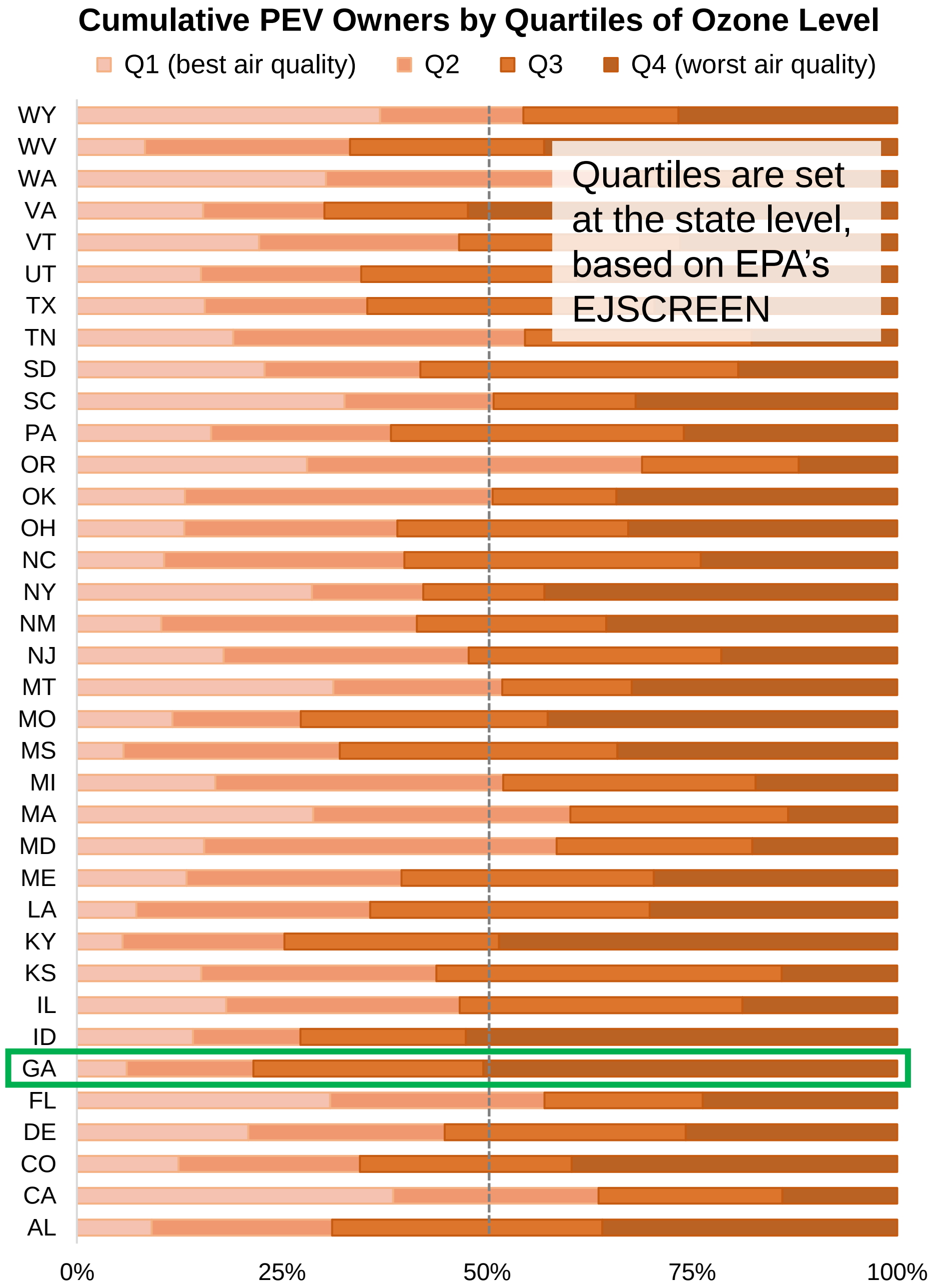
Concentration of Ground-level ozone (smog)

Low High

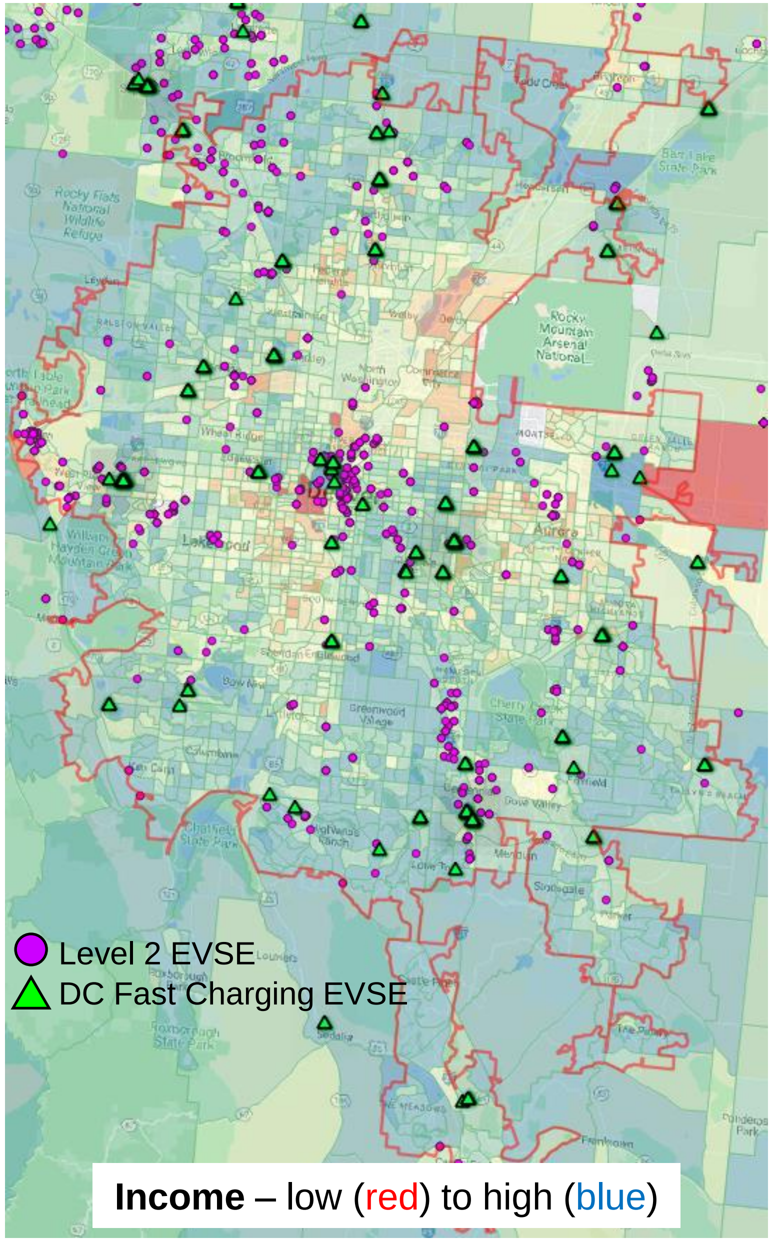
● Level 1 and Level 2 EVSE

△ DC Fast Charging EVSE

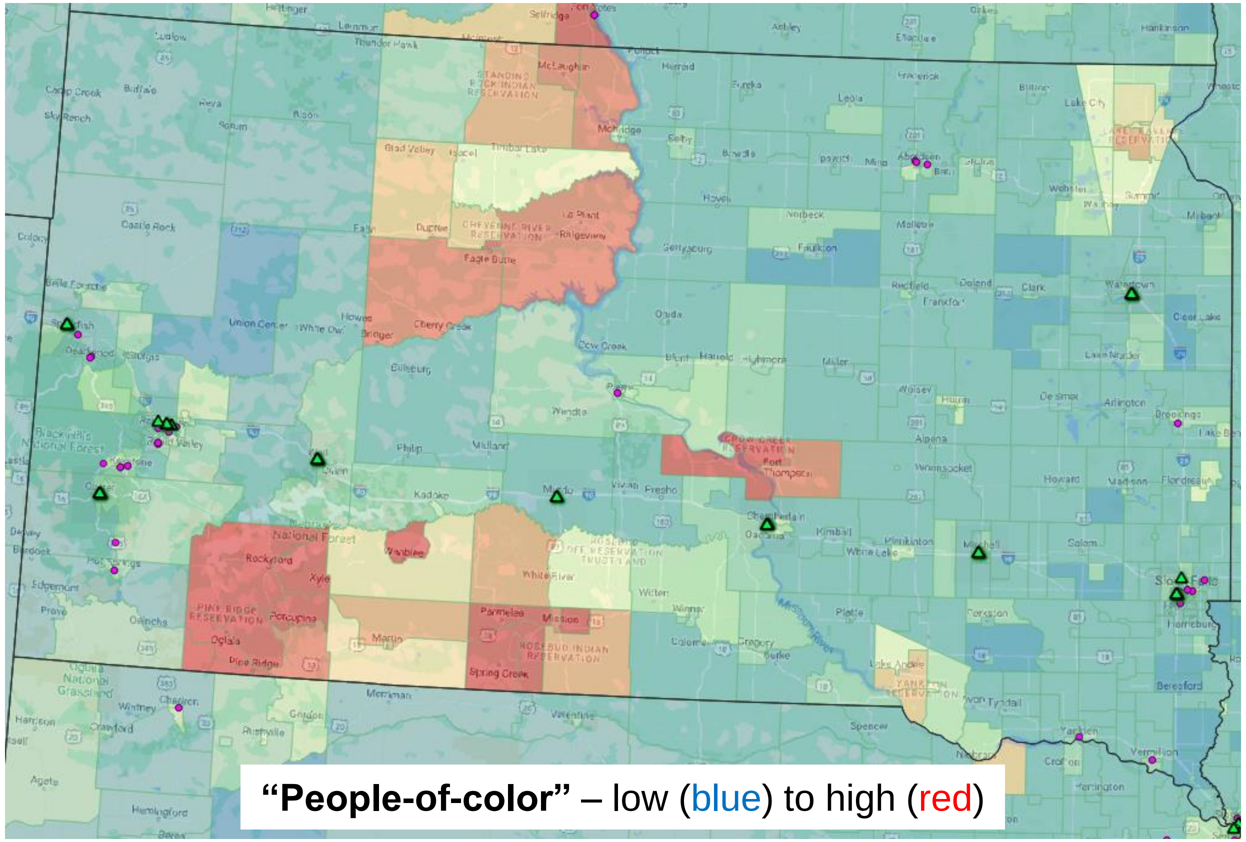
For environmental profiling analysis, a wide variety of environmental factors were examined. Only ground-level ozone is shown here, as an example.



Two Example Areas: Denver Urbanized Area & South Dakota



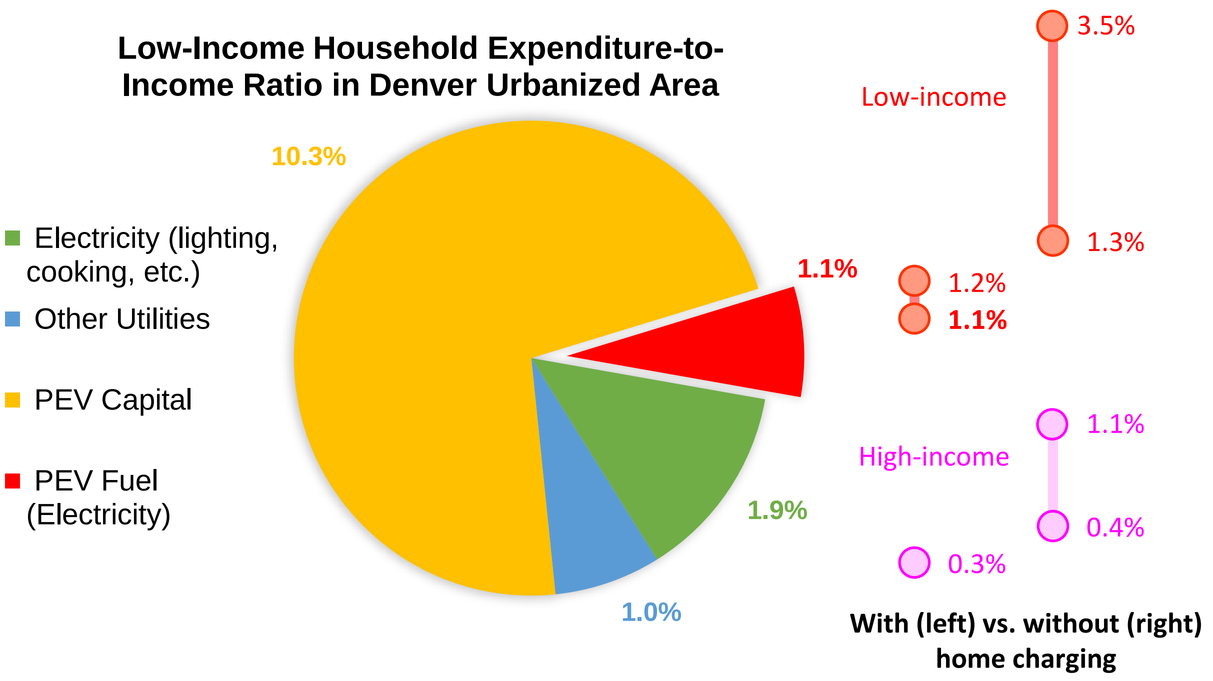
	Denver	SD
PEV population	15,000	760
Public L2 (excluding workplace chargers)	690	75
Public DCFC (excluding workplace chargers)	180	63



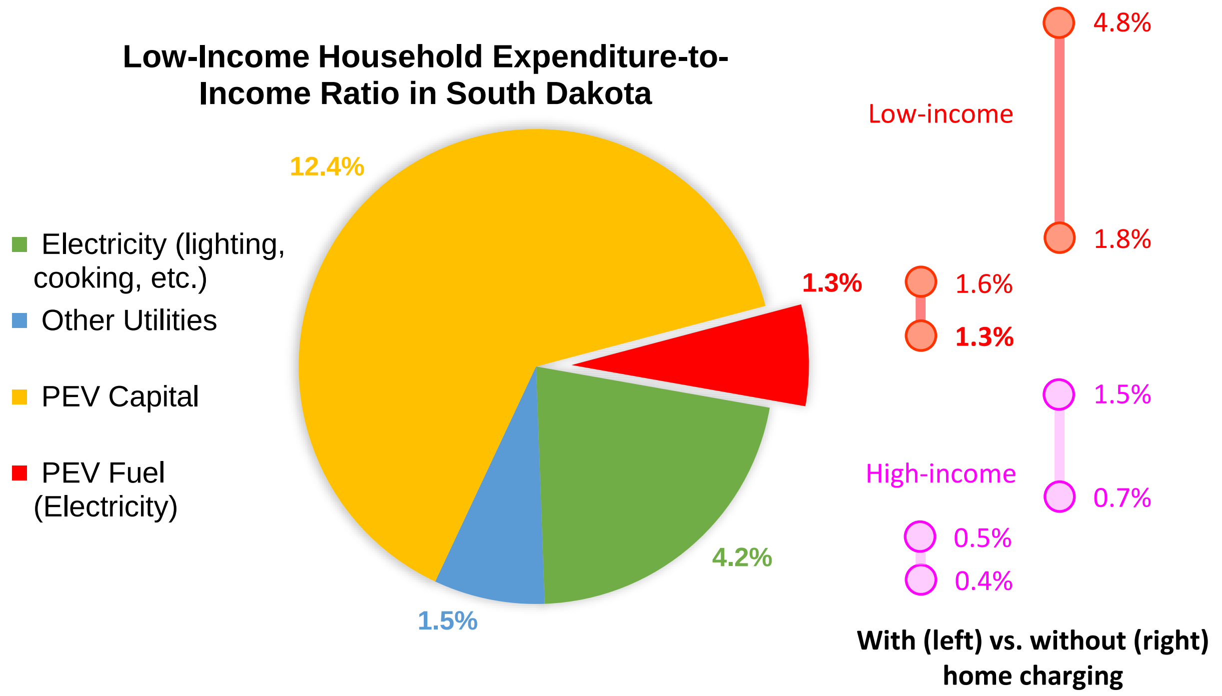
Accomplishment: Home Charging Access & Household Expenditures

Preliminary

- Ability to refuel/charge at home is one of the most significant benefits of electric vehicles (compared to their conventional petroleum counterparts). However, not everyone has home charging access, raising equity concerns.
- Not having home charging access, and thus relying on public charging, can increase electricity fuel cost significantly.
- The increased electricity fuel cost, due to the lack of home charging access, affects lower-income households even more.



On average, households in the **Denver** area, below area-wide median income, with both PEVs and home charging access, pay **1.1–1.2%** of their income as PEV fuel (electricity, per PEV) from home and public charging. For households making above area-wide median income, it is **0.3%**.



On average, households in **South Dakota**, below state-wide median income, with both PEVs and home charging access, pay **1.3–1.6%** of their income as PEV fuel (electricity, per PEV) from home and public charging. For households making above state-wide median income, it is **0.4–0.5%**.

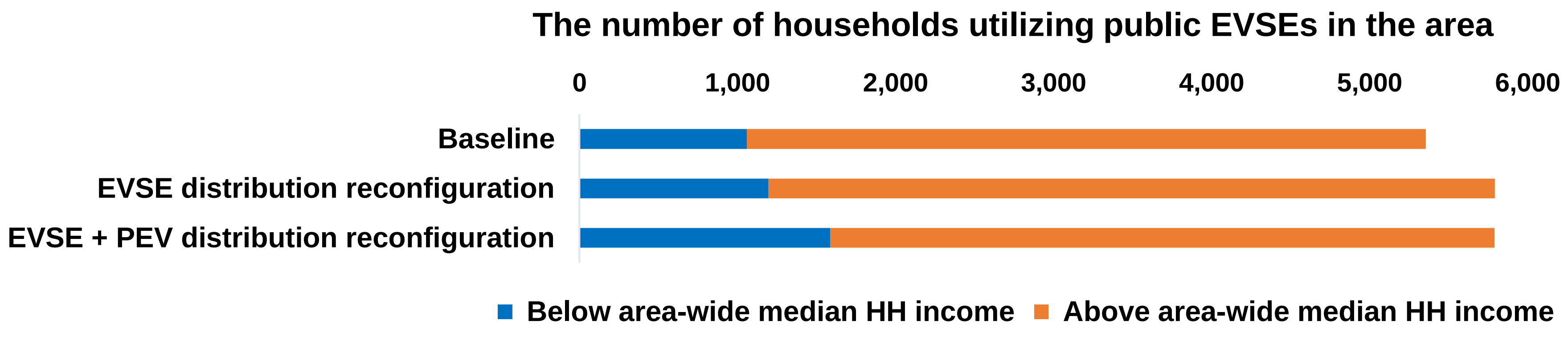
Accomplishment: Network Design for Improved Equity

Preliminary

- Adding more public EVSEs (shared resources) in disadvantaged neighborhoods increases access to all PEV drivers.
- Coordinating EVSE deployment and PEV adoption can lead to better (distributional) equity outcomes.
- Adding more public EVSEs can help those who don't have home charging access, but the impact may be limited.
- Reducing/assisting home charger "orphans" may require a different approach.
- Manipulating one lever/dimension (e.g., income) leads to complex interactions with the other levers/dimensions (e.g., race).

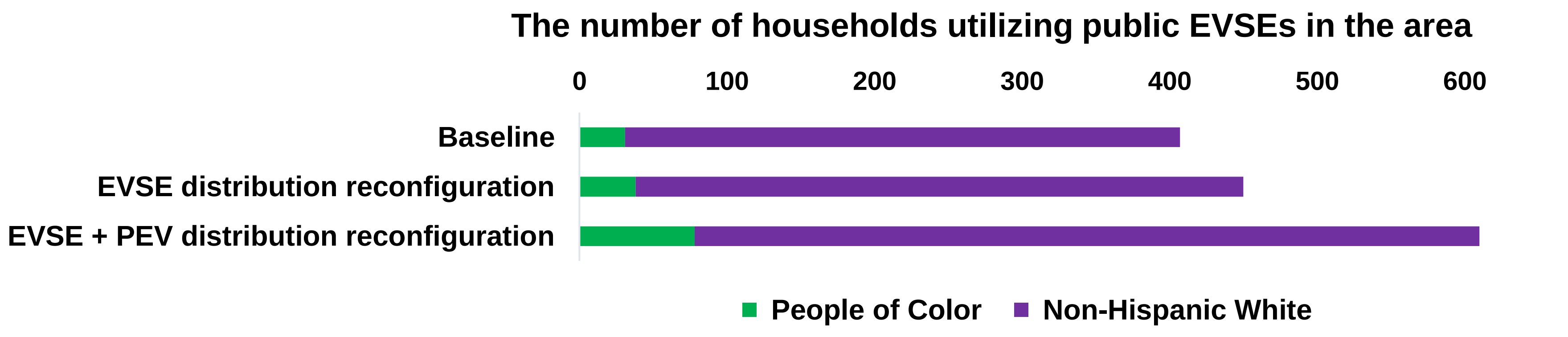
Denver urbanized area:

What if we increase the number of EVSEs (and PEVs) in low-income CBGs by 50%, while keeping existing EVSEs (and PEVs) in place?



South Dakota:

What if we increase the number of EVSEs (and PEVs) in CBGs with a higher percentage of "people-of-color" by 50%, while keeping existing EVSEs (and PEVs) in place?



Responses to Previous Year Reviewers' Comments

Not applicable – was not reviewed in 2021 AMR.

Collaboration and Coordination with Other Institutions

- Collaborated with international experts on electrification, environmental justice, and energy equity:
  - Georgia Institute of Technology
  - Boston University
  - University of Sussex
  - Rutgers University
  - UCLA Luskin Center
  - Dartmouth College
  - University of California at Davis

- External collaborators (listed above) helped the team collect the data (e.g., empirical refueling behavior) and provided feedback and guidance on concepts and methods for EVI-Equity

- Coordinated with other EERE efforts (e.g., buildings, electric grid) at NREL related to equitable energy technology adoption

- Engaged in brainstorming sessions with the Energy Information Administration (EIA), U.S. EPA, California Energy Commission, National Association of State Energy Officials, and others

Proposed Future Research

- EVI-Equity is currently focused on distributional equity (“equitable access to all”). Other important equity aspects/dimensions (e.g., economics of charging infrastructure) could be considered.

- Incorporate NREL’s EVI-Pro (daily short-distance), EVI-RoadTrip (long-distance road trips), and EVI-OnDemand (ride-hailing) for a more comprehensive and accurate EV charging infrastructure analysis for future years

- Expand the scope beyond light-duty vehicles, including medium- and heavy-duty vehicles (e.g., electric para-transit vehicles, school buses, transit buses)

- Create an interactive online platform so that users can evaluate equitable distribution of PEVs and EVSEs in their target geographical areas and download the underlying data and simulation results

- More holistic (i.e., system-of-systems) equity analysis by integrating EVI-Equity with buildings and/or electric grid simulation tools/models

Any proposed future work is subject to change based on funding levels.

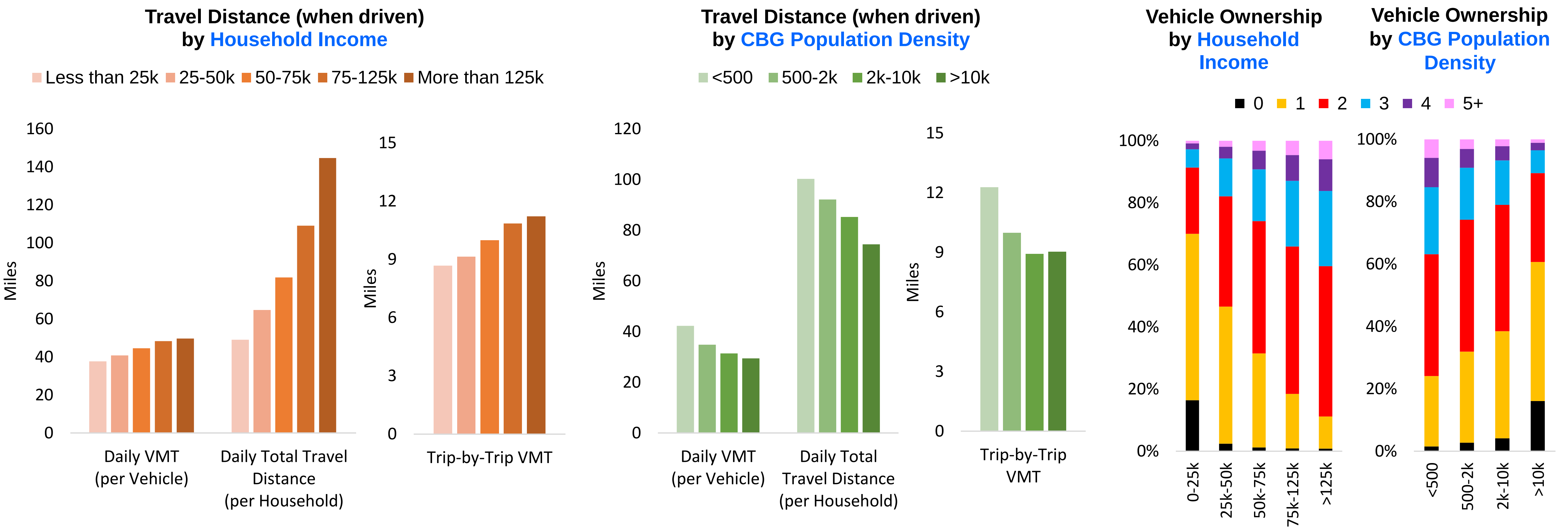
Summary

- Created a simulation model (EVI-Equity) that can evaluate equitable access to PEVs and EVSEs based on individual households in each and all census block groups in the U.S., accounting for household-level travel patterns, charging needs, refueling behavior, and other factors
- Applied EVI-Equity to local, state-by-state, and national analyses of equitable deployment of PEVs and EVSEs
- Conducted a large-scale survey (22,000 respondents across the country) to examine public perception, preferences, and behaviors related to alternative transportation modes, perceived barriers to and benefits of electrification, housing type, parking options, power outlet availability, home charging access, vehicle purchase, vehicle utilization, and refueling behavior and preferences. The survey results provided one of the key input data sets for EVI-Equity.
- Examined a wide variety of environmental factors (e.g., air pollution, crime rate) in order to identify the characteristics of disadvantaged, underrepresented, and underserved neighborhoods.
- Investigated detailed household expenditures, and what PEV adoption means for different households in terms of their overall income and expenditures, given the key role of home, workplace, and public charging access.
- Evaluated alternative (more equitable) charging station network design strategies and corresponding impacts (e.g., how many disadvantaged households are benefitting and how much).

Technical Backup Slides

Technical Backup Slide: Driving Distance and Vehicle Ownership

- In general, lower-income households travel less (frequency or distance) and own smaller number of vehicles.
- On a per-vehicle basis, average daily driving distance (when driven) is a little shorter for low-income (40 vs. 50 miles/day).
- On a per-household basis, average daily total travel distance is much shorter for low-income (50 vs. 150 miles/day).
- The number of vehicles per household increases with household income but decreases with population density.
- About 20% of households, with $25k-or-less of annual income, or in highly-populated areas, do not own personal vehicles.

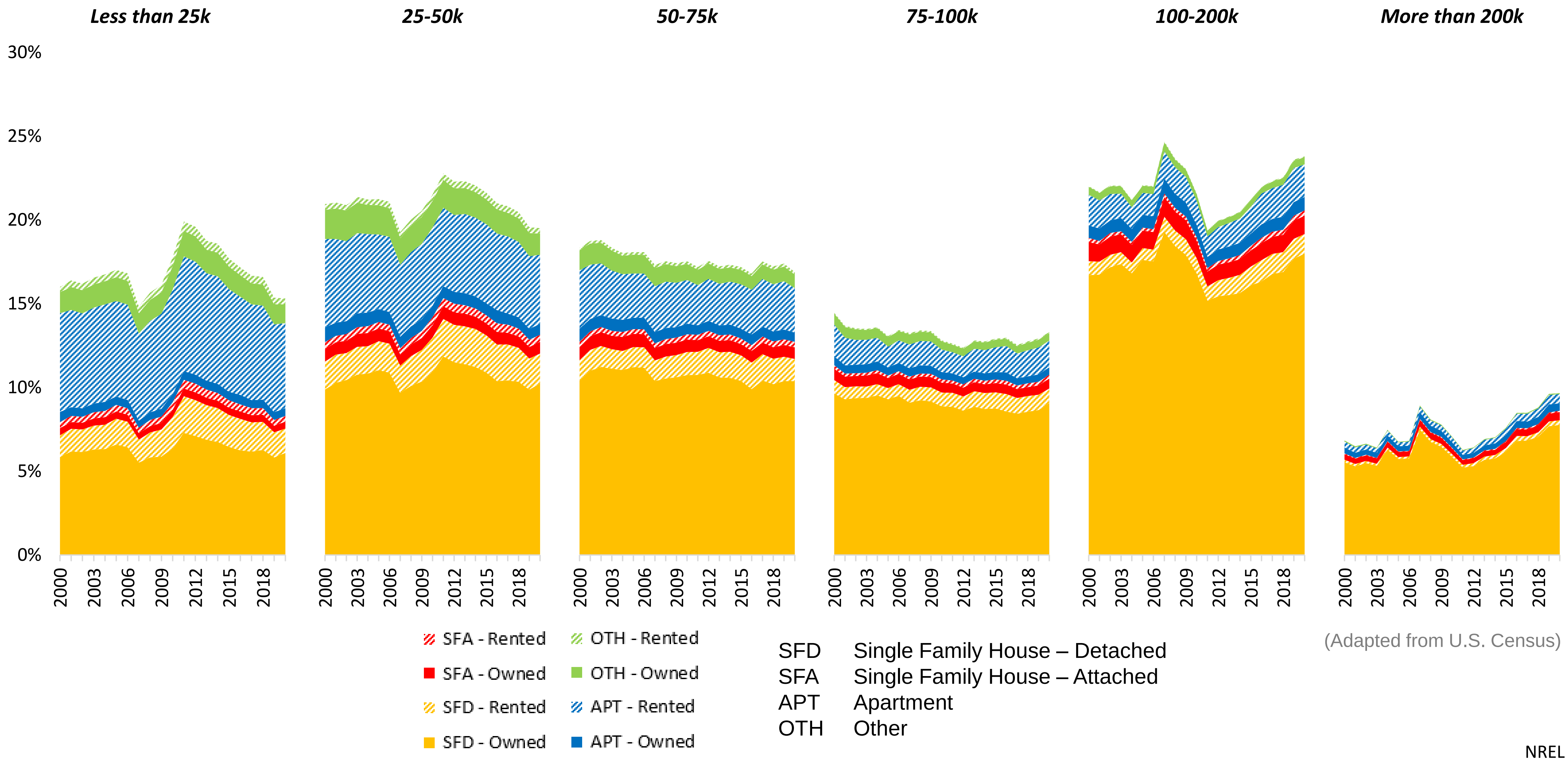


(Adapted from National Household Travel Survey)

Technical Backup Slide: Housing Type

Housing Type by Household Income in the U.S.: 2000–2020

Housing type affects available parking options, which in turn determines power outlet availability and home charging access.



SFD	Single Family House – Detached
SFA	Single Family House – Attached
APT	Apartment
OTH	Other

(Adapted from U.S. Census)

Technical Backup Slide: Community Engagement – Public Survey

- Regardless of income, retail locations seem to be the most preferred public charging location.
- Street/curbside chargers are second most preferred location.
- Gas stations are third most preferred location, except for 100K+ income groups, who rank workplace charging in third spot.

If you ever buy a plug-in electric vehicle in the future, or if you already have one,
which public charging option (in addition to home/residential) would you prefer,
assuming they are installed and available? Please rank from the most preferred to the least.

Income: $15k or less

Item	Overall Rank	Rank Distribution
Not applicable (do not [plan to] own electric vehicle[s])	1	
Retail locations (grocery store, shopping center, etc.)	2	
Street/curbside charger in your neighborhood	3	
Gas stations – could be faster but more expensive than the other options	4	
Workplace	5	
Transit stations (Park N Ride)	6	
Somewhere else	7	

Lowest Rank   Highest Rank

Income: $150k or more

Item	Overall Rank	Rank Distribution
Retail locations (grocery store, shopping center, etc.)	1	
Street/curbside charger in your neighborhood	2	
Workplace	3	
Gas stations – could be faster but more expensive than the other options	4	
Not applicable (do not [plan to] own electric vehicle[s])	5	
Transit stations (Park N Ride)	6	
Somewhere else	7	

Lowest Rank   Highest Rank

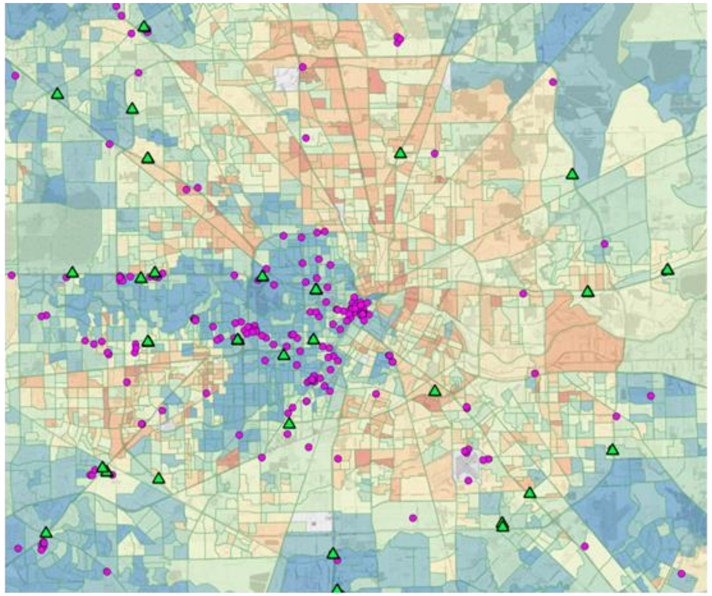
NOTE: More than 30 questions were asked about electric vehicles, refueling behavior and preferences, and charging infrastructure.

Technical Backup Slide: “Houston, We [May] Have a Problem”

Percent of
Low Income HH

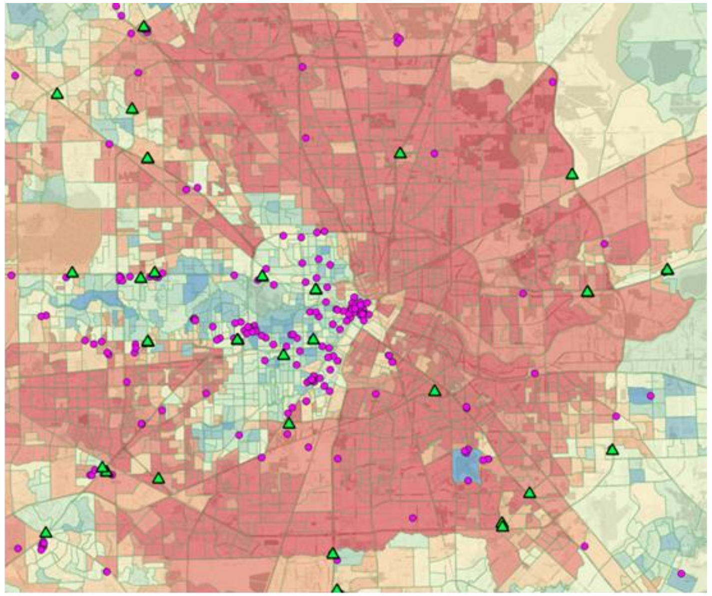
Low High

▲ Public DCFC
● Public L2



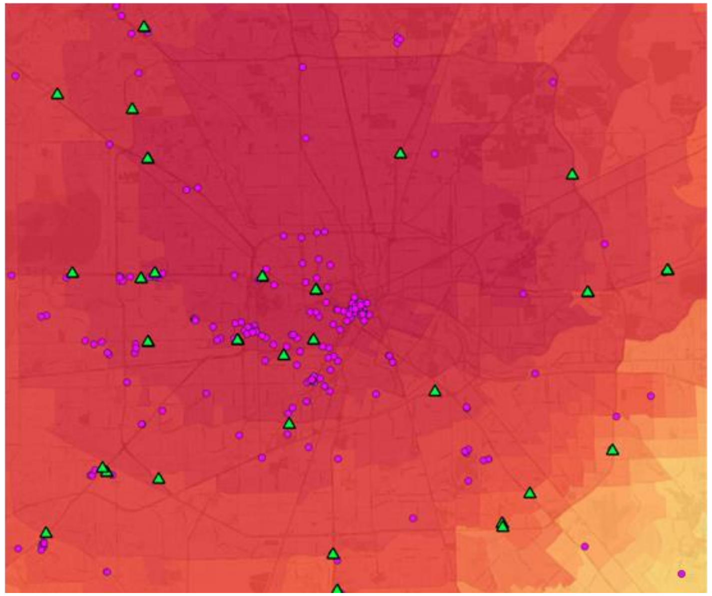
Percent of
“People of Color”

Low High



Percent of
PM2.5

Low High



Percent of
Ozone

Low High